

Evaluation of Title 24 Acceptance Testing Enforcement and Effectiveness



Submitted to:
California Energy Commission

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Executive Summary

This research evaluated Title 24 acceptance testing requirements and enforcement procedures to characterize the challenges, limitations, and opportunities for achieving the intended minimum standards of energy efficiency. The researchers evaluated the effectiveness of the existing acceptance test procedures based on how well contractors understand the acceptance test requirements and the clarity of the test procedures and associated forms. The product of this research is a set of recommendations for changes to the Title 24 acceptance testing forms, enforcement procedures, and for training and outreach.

These recommendations are the result of a two-part study. In the first part, researchers interviewed stakeholders to understand how each participates in the acceptance testing process and to identify situations where the process may break down. In the second part of the study, researchers investigated the ability of HVAC and lighting contractors to effectively implement specific acceptance test procedures.

Phone Interviews

A total of 31 phone interviews were conducted with stakeholders, including building officials, testing contractors, design engineers, and building owners. In addition, researchers visited several building departments for a first-hand view of their processes. These interviews and site visits produced several key findings:

- Building departments are underfunded and understaffed, thus acceptance forms receive little review, and plans examinations are often outsourced to local engineering firms.
- Building departments and the firms they employ need an improved understanding of the testing procedures and the methods for reviewing test forms. More importantly, they need successful models of enforcement that illustrate practical approaches for improving compliance.
- The “Responsible Party” is very often not specified on the forms. Thus, it is unclear who is responsible to execute tests, which can contribute to omission of the tests.

It is noted that the Energy Commission website provides a comprehensive resource of support documentation, helpful checklists for building department reviewers, and short video tutorials. In addition, the California Commissioning Collaborative (with funding from the Energy Commission) has developed a hands-on training workshop curriculum for building departments. This indicates that any lack of understanding of requirements among building departments is not simply due to lack of training opportunities.

Field Testing

To determine the effectiveness of the acceptance test procedures, eight different contractors were enlisted to perform multiple acceptance tests at 13 commercial high-rise and low-rise buildings. The researchers observed and recorded the actual procedures used in the resulting 48 acceptance tests. A comparison of the observed procedures with the specified Title 24 procedures and feedback from the contractors yielded the following conclusions:

- Most contractors are at least somewhat familiar with the tests. However, the field testing indicated that often their perceived level of understanding exceeded their actual ability to perform the specified tests.
- Technicians are not aware of reference materials such as the Compliance Manual.
- Confusion arises in interpretation of the procedures, as the tests are complex and the forms are unclear.
- Contractor training is insufficient. Approximately half of the tests could not be performed without a moderate or substantial level of coaching.

Based on the findings from the two parts of this study, the researchers have proposed changes for the 2013 Title 24 acceptance test requirements. The revisions clarify test procedures and add references to additional resources, which will make it easier for testing contractors to conduct effective tests. The researchers recommend that these changes be incorporated into the official Title 24 acceptance testing documentation to help improve compliance with these provisions.

Overall, this research illustrates that the success of the Title 24 acceptance requirements depends on a chain of responsibility linking design engineers, contractors, sub-contractors, owners and building officials. For each link in that chain to hold strong requires training on acceptance testing procedures and motivation to change the existing practices for contracting and code enforcement. Thus, a key outcome of this report is a set of specific recommendations for training and outreach to building officials, owners, engineering firms, and contractors.

1 Introduction

California's Title 24 was conceived in 1978 as the State's comprehensive building energy code. It contains standards governing many aspects of building design, including building energy efficiency. The energy efficiency provisions of Title 24 have often been at the forefront of energy code development, with acceptance testing being a good example of this. Since 2005, Title 24 has required acceptance testing of lighting and mechanical systems in new buildings, major renovations, and equipment change-outs. These acceptance tests are meant to ensure that building systems were installed and function in conformance with code and as specified in the building's design.

The Title 24 acceptance testing must be performed by one or more of the parties involved in design and construction—an installation contractor, an air balancing contractor, the engineer of record, or an agent of the building owner. Compliance with the testing requirement is enforced by California's city and county governments. Specifically, these local building departments must ensure that the tests have been conducted by a competent party and that the required documentation has been provided before issuing occupancy permits.

Ensuring compliance with Title 24 is important to achieving the State of California's energy policy objectives. It is also a task that requires ongoing attention. New code provisions introduce requirements for builders and building officials that can easily be overlooked without supporting materials and training. Previous studies by the Heschong Mahone Group¹, Quantec², and PG&E³ have explored the necessary components for improving compliance with Title 24. This project builds on those previous works by looking for opportunities to improve compliance with the acceptance requirements of Title 24.

This project was conducted in two parts. The first part focused on acceptance testing compliance, to gain an understanding of the roles and responsibilities of stakeholders in the compliance process. The second part consisted of field evaluations of acceptance tests. For both parts, the overarching goal was to identify and provide recommendations to improve implementation of the acceptance requirements. This report discusses the methods and findings for each part, and then concludes with a summary of findings and the recommendations for a 2013 update of the Title 24 acceptance requirements and supporting documents.

2 Acceptance Testing Compliance

The goal of this part of the project was to identify opportunities for improvement in the compliance process. Here, the compliance process is defined as the completion, submittal and review of acceptance forms according to Title 24 acceptance requirements. A detailed illustration of the steps required to ensure compliance is shown in Figure 1 below.

¹ HMG facilitated a roundtable discussion involving a variety of California policy stakeholders (including utilities, CEC, CPUC). The report (*SCE Codes & Standards Process and Market Assessment Study*, 4/15/2009) is available at <http://www.calmac.org>

² Quantec. *Statewide Codes and Standards Market Adoption and Noncompliance Rates*. Prepared for SCE, Final Report CPUC Program No. 1134-04. May 10, 2007.

³ Misti Bruceri and PG&E surveyed building officials via CALBO (California Building Officials) for a codes education program

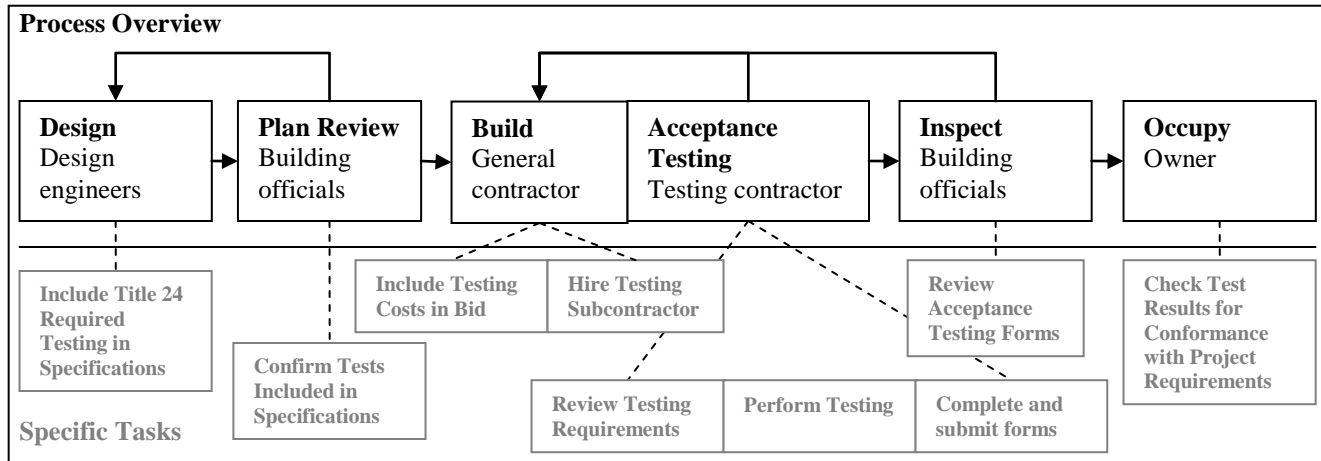


Figure 1: The acceptance testing compliance process and the specific tasks it involves

2.1 Research Methodology

The researchers interviewed each of the major stakeholders in the compliance process: design engineers, building officials, testing contractors, and building owners. Examining acceptance testing compliance activities from the viewpoint of each of these stakeholders allowed the researchers to document the ways the compliance procedure breaks down, is misunderstood, or becomes onerous. These findings support a suite of recommendations that, if implemented, would collectively improve the clarity and reduce the complexity of the process.

Phone Interviews

Through 31 phone interviews, the researchers documented and evaluated acceptance testing compliance activities from the viewpoint of each of the major participants. The interview respondents are shown in Table 1.

Table 1: Phone interview respondents

Stakeholder Group	Qty	Description
1. Building officials	8	Inspectors who had previously participated in utility sponsored training and others who had not; officials from diverse jurisdictions, including high-density metropolitan areas, rural districts, areas with strict enforcement and areas with lax enforcement.
2. Building owners (typically represented by an energy manager)	6	Building owners with projects completed within the past three years of this study. This includes owners with small and large portfolios, projects in rural and urban sites, and across a range of building types and sizes.
3. Testing contractors	10	HVAC, lighting, and controls contractors who serve rural and urban sites.
4. Design engineers	7	Design engineers located throughout California
Total	31	

The researchers selected interview participants through a variety of channels and with input from several groups. The PIER Technical Advisory Group provided suggestions, as did the Building Owners and Managers Association (BOMA). Additional respondents were identified based on their previous participation in California

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Commissioning Collaborative and utility-sponsored programs and training, by internet search, and through referrals from other building professionals.

The interview questions for the four groups are provided in Appendix A. For each group, the interview began by assessing the respondent's general knowledge of the acceptance testing requirements and then examined his or her understanding of and adherence to specific requirements. Respondents were also given opportunities to self-identify problems in the compliance process and to describe their preference for receiving training and other support.

After completing the phone interviews, the researchers summarized the responses of each group in a matrix that allowed for easy identification of common themes within and across the groups. These matrices are presented in Appendix B. With the exception of the design engineers, most groups exhibited a variety of experiences with and opinions about the acceptance testing requirements. This diversity is reflected in Table 2 below.

Building Department Visits

After completing the phone interviews and interpreting the results, the researchers visited four building departments in different jurisdictions in July and August 2010. The group met with chief building officials, inspectors, and plans examiners for approximately 90 minutes at each of the four locations. The group also reviewed a number of commercial building plan sets to further understand each jurisdiction's method of processing acceptance forms. Through the meetings and observation of the process, the researchers identified barriers to compliance related to staffing, tools, and forms.

2.2 Findings

The phone interviews provided insights into the challenges around Title 24 acceptance testing compliance; in some cases the findings were general in nature, relating to levels of understanding and training, and other findings were specific to particular stakeholder groups. Key observations are summarized in Table 2 below.

Table 2: Summary of phone interview responses

Summary of code official responses
<ul style="list-style-type: none">• Six of the eight officials stated the acceptance requirements are confusing and not easy to understand• All four officials who answered the question about common problems stated the contractors are unfamiliar with the forms, incorrect forms are commonly used, and rework is needed 50% of the time• One building official answered that completed forms are not needed to grant a certificate of occupancy• Only two officials do any onsite verification of the acceptance testing results• Building officials typically process around 4 to 6 projects with acceptance testing each month• Building officials find online and printed training materials to be a valuable resource
Summary of contractor responses
<ul style="list-style-type: none">• Seven of the ten interviewed contractors perform acceptance testing• Three who do not perform tests stated commissioning agents and electrical engineers should perform the tests• Two contractors stated the acceptance requirements and forms are not easy to understand• The Sacramento and Orange County areas were reported to strongly enforce acceptance requirements• Not all contractors include acceptance testing in their project bids (to be price competitive)• Three of the ten contractors stated that building officials request the completed acceptance forms
Summary of building owner responses
<ul style="list-style-type: none">• Four of the six interviewed building owners are familiar with the tests• Three of the building owners stated the tests are valuable as a way to identify potential problems• One building owner stated the tests are of low value because they don't require that the tests be conducted by a third-party testing agency as is required by LEED• Two of the six owners interviewed were not at all familiar with the acceptance tests or their requirements

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Summary of design engineer responses

- All seven design engineers are familiar with the acceptance requirements
- All stated they or other project engineers are responsible for determining which tests are required
- All stated the installing contractor is responsible for completing the tests
- Five of the seven engineers reported that the requirements are confusing
- Five of the seven engineers require the cost for testing to be included in the installer's project bid

The researchers found two main causes for a breakdown in the compliance process based on phone interviews. The first cause is the difficulty of interpreting the requirements and the associated forms. A majority of the stakeholders with a hand in performing or enforcing the acceptance testing requirements found those requirements to be confusing. This perception was shared across groups. The researchers also interpret the diverse statements about acceptance form submittal requirements and the reportedly high frequency of incorrectly completed forms as pointing to lack of clarity in the forms themselves.

The second cause of breakdown in the compliance process that the researchers identified through the interviews is a lack of clarity about who is responsible for key parts of the process. This could be related to the difficulty in interpreting the requirements, but it causes a series of problems and is worth calling out separately. Though the design engineers consistently identified the engineering team as responsible for specifying the types of acceptance tests required, they were less uniform in their requirement that contractors include the cost of testing in their bids. The contractors were even less consistent in their responses as to which party is responsible for administering tests. The lack of clarity in the chain of responsibility potentially leads to a disincentive for including testing costs in project bids. Contractors who include those costs increase their risk of being underbid by a competitor who has excluded the costs.

Building department visits provided a deeper understanding of the enforcement process from a critical stakeholder group – the building department officials. Observations from these visits are summarized in Table 3.

Table 3: Barriers to compliance identified in building department visits

Area	Observation
Staffing	The building officials at all four jurisdictions reported their departments are understaffed due to funding constraints. As a result, the acceptance forms receive little to no review.
	The department's staff does not have adequate training on acceptance test requirements and contractors are not being trained on the process. Inadequate training has resulted in frustrated contractors and low enforcement from building departments.
Tools	While reviewing a number of commercial building plan sets, it was apparent that the energy compliance software used to generate the Certificates of Compliance (ENV-1C, MECH-1C and LTG-1C) had errors. For example, in one new construction project a MECH-4A "Air Distribution Systems Acceptance" test was called for by the software, but the review of the HVAC system showed that it was not actually required. This error is likely due to a bug in the compliance software, which resulted in the software specifying an unnecessary test.
	Staff and contractors would benefit from access to experts who could answer their questions about the acceptance testing requirements. The CEC's Energy Hotline offers such a resource, but contact information is not provided on the three most used documents related to acceptance testing: the forms, the Nonresidential Appendix NA7, and the Nonresidential Compliance Manual Chapter 10.
Forms	The Responsible Party for performing the acceptance tests is not documented on the ENV-1C, MECH-1C and LTG-1C forms. Though the forms provide a space for specifying the testing firm or person, the researchers identified four projects with no responsible party identified.
	Three building departments reported that there are too many acceptance forms, which increases their workload, complicates their review process, and adds to industry confusion. For a building with a unitary HVAC system, for example, the MECH-2A, 3A, 4A, and 5A forms can all be required, plus lighting and envelope forms. A built-up central system may require MECH-2A, 5A, 7A, 9A, and 10A forms, plus lighting and envelope forms.

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The visits to the building departments pointed to the breakdown in the compliance process that occurs due to the inadequacy of the existing resources: Staff are short of time and training, errors or omissions were found in the tools these staff rely on, and the forms used in the compliance process are too numerous and often incomplete when submitted. The deficiencies identified in tools and forms are relatively easy to correct.

Providing all parties involved with the time and training that they require is a more difficult proposition under the existing funding constraints. The recommendations presented later in this report include several ideas for improving training and reducing the complexity of the compliance process that will not require a large increase in funding. Part of the solution may be to better leverage existing training resources, including:

- The CEC website has a comprehensive array of resources for building department officials, including many brief training videos (available on demand) and plan review checklists to guide officials through document review.
- The California Commissioning Collaborative has worked with industry partners to develop an in-person training program for building department officials (with curriculum development funding provided by the CEC). Training workshops commenced in early 2010, and were suspended in late 2010 due to low enrollment. At the time of writing this report, plans for this training program are under review.

Connecting the findings from this project with the two points above, the conclusion is that there is not a serious lack of training opportunities for building department officials, but that one of the following is true:

- Building department officials are unaware of what is available to them in terms of training
- The training and support materials do not meet the needs of building department officials (e.g. they don't adequately explain the process and documentation)
- Building department officials feel they do not have time to take advantage of the training opportunities, or are perhaps unmotivated to participate.

Aside from the building department officials, there appears to be a lack of formal training and support materials for the other identified stakeholder groups, although this project did not conduct a comprehensive review to confirm this.

3 Field Evaluation of Acceptance Tests

The goal of investigating the actual performance of acceptance tests was to identify barriers to successful completion of the tests. The researchers chose to focus the investigation on several areas where the interviews had suggested barriers may exist: the ability of contractors to understand and follow the test procedures, the availability of the tools needed for testing, and the ease of use of the forms.

3.1 Research Methodology

The approach in this part of the project was to observe actual acceptance tests in the field. In total, the researchers observed eight contractors performing 48 tests in 13 different commercial buildings. Observing the tests, evaluating the test results, and a series of interviews with the contractors enabled the researchers to detect barriers to successful performance of the tests. The stages in this part of the project are shown in Figure 2 below.

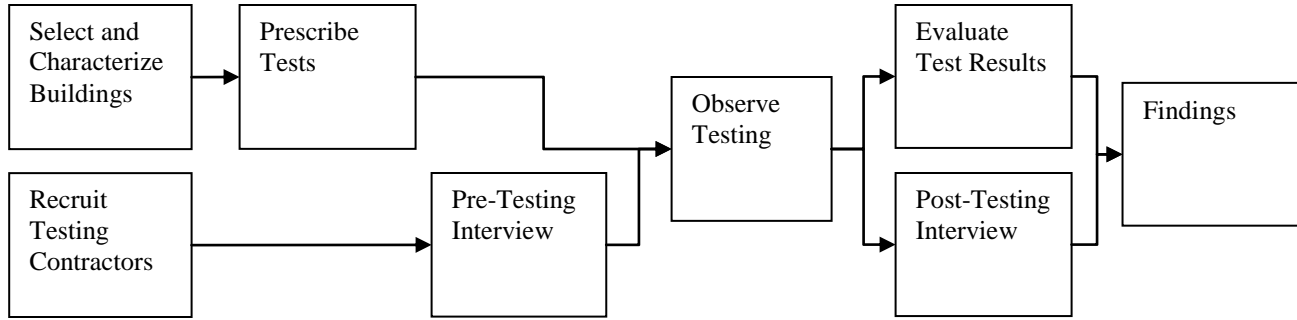


Figure 2: Methodology for evaluating the performance of acceptance tests

Participating Buildings

The researchers selected buildings for the project with the help of interested building owners. Candidate building owners were suggested by building departments and contractors, or identified through their previous participation in retrocommissioning programs and research projects. Owners who were familiar with acceptance tests were willing to participate in this study because the tests represented a free evaluation of their HVAC and lighting systems.

The 13 buildings selected for the project have diverse characteristics. Though they are not fully representative sample of the State’s buildings, they do include many of the common systems that are subject to acceptance testing. They represent two climate zones, two compliance jurisdictions, a variety of equipment, and a corresponding variety of testing opportunities. Some were built before the 2008 Title 24 acceptance testing provisions were in effect and others were built subject to those provisions. It was desirable if the building had undergone previous acceptance testing prior to occupancy, but it was not a requirement. Table 4 below summarizes the relevant equipment in each building, whether acceptance tests were required by code at the time of construction, and whether the tests had previously been performed. The last of these items is included to account for possible non-compliance with the code requirement.

Table 4: Summary of Building Characteristics

Building ID ⁴	Climate Zone	Equipment	Acceptance Test Required When Constructed?	Acceptance Tests Performed Originally?
1	12	Constant Volume AHU Fan Coil Unit Automatic Lighting Controls	Yes	Unknown. Commissioned as part of LEED, but documents were not available for review.
2	12	Constant Volume AHU VAV AHU Exterior lighting on timeclock	No	No
3	8	VAV AHU Occupancy sensors	Yes	No
4	8	Constant Volume AHU	Yes	No
5	8	VAV AHU	Yes	No
6	8	VAV AHU	Yes	No

⁴ A pre-condition of participation in this research was that building names, addresses and owner would not be identified in project-related reports.

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Building ID ⁴	Climate Zone	Equipment	Acceptance Test Required When Constructed?	Acceptance Tests Performed Originally?
7	8	VAV AHU	Yes	Compliance Certificate 1-C shows MECH-2A, 3A, 4A, 5A, 6A, and 8A were completed but documentation was not available for review.
8	8	Central Plant with VAV on each floor Hot water reheat via gas boiler Pneumatic T-stats DDC NOT to zone level	Yes	Yes
9	8	Central Plant with VAV on each floor Hot water reheat via gas boiler Pneumatic T-stats DDC NOT to zone level	No	No
10	12	Automatic Lighting Controls	No	No
11	12	Central Plant with VAV	Yes	Yes

Tests Performed

The researchers prioritized nine acceptance tests in this project because a previous study for PG&E suggested that they represent the greatest energy saving opportunities.⁵ Four additional tests were conducted and evaluated during the study because of the availability of the relevant mechanical systems at two of the high rise office buildings with central plant HVAC systems. Each test and the number of times it was performed is shown in Table 5 below.

Table 5: Acceptance Test Performed

Test ID	Form	Test Name	Times Performed
NA7.5.1.1	MECH-2A	Variable Volume Outdoor Air Acceptance	5
NA7.5.1.2	MECH-2A	Constant Volume Outdoor Air Acceptance	3
NA7.5.2	MECH-3A	Constant Volume, Single-Zone, Unitary AC and Heat Pump	5
NA7.5.3	MECH-4A	Air Distribution Systems	3
NA7.5.4	MECH-5A	Air Economizer Controls	8
NA7.5.6	MECH-7A	Supply Fan Variable Flow Controls	10
NA7.5.8	MECH-9A	Supply Water Temperature Reset Controls	2
NA7.5.9	MECH-10A	Hydronic System Variable Flow Controls	1
NA7.6.1	LTG-3A	Automatic Daylighting Controls Acceptance	7
NA7.6.2	LTG-2A	Occupancy Sensor Acceptance	1
NA7.6.3	LTG-2A	Manual Daylighting Controls Acceptance	1
NA7.6.4	LTG-2A	Automatic Time Switch Control Acceptance	1
NA7.7.2	OLTG-2A	Outdoor Lighting Shut-off Controls	1
Total tests performed			48

⁵ Prioritization based on first year statewide annual electric energy savings reported in Evaluation of Nonresidential Acceptance Requirements. Final Report. September 2005. Hershong Mahone Group for PG&E.

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A total of 48 tests were conducted during the field study. One to five tests were performed at each site, depending on the equipment available in the building. MECH-2A, MECH-5A, and MECH-7A were performed the most often. LTG-3A was only performed numerous times but only at two sites due to the difficulty in locating facilities with the applicable lighting control system.

Testing Contractors

To perform the tests, the researchers recruited contractors whom they had worked with on previous projects or who were suggested by building owners. Some contractors were already familiar with their assigned buildings because they had performed services on the building during the equipment start-up or test and balance period. In some cases, the researchers deliberately selected an alternate contractor who had not been involved with the initial start-up of the systems, to control for bias that may come from previous knowledge of the building.

Eight contractors were selected to perform the tests. Three were from the Sacramento region and five from the Orange County region. To facilitate an open exchange with the contractors, the researchers agreed to maintain anonymity in the report. A list of the contractors' characteristics is provided below.

Table 6: Contractor characteristics

Contractor ID	Type	Region	Familiar with assigned building(s)?
1	Test, Adjust, & Balance (TAB)	Sacramento	No
2	Test, Adjust, & Balance (TAB)	Sacramento	Yes
3	C20 HVAC contractor (Installation and Start-up)	Orange County	No
4	C20 HVAC contractor (Installation and Start-up)	Orange County	No
5	C20 HVAC contractor (Installation and Start-up)	Orange County	No
6	C20 HVAC contractor (Installation and Start-up)	Orange County	No
7	Mechanical Service contractor	Orange County	No
8	Electrician ¹	Sacramento	Yes

¹ The electrician performed only lighting tests.

Contractor Interviews and Observation of Testing

Having selected buildings, contractors and acceptance tests, the approach was then to interview the contractors, observe the testing, and finally interview the contractors again. This combination of interviews and field observation provided valuable insight into how acceptance testing actually happens, which in many cases diverges from the intent of Title 24. Identifying these divergences and diagnosing their root causes allowed the researchers to make recommendations for updating the acceptance testing requirements of Title 24.

The pre-testing interview was conducted to gauge how well the contractors understood the test requirements and to document their general impressions about the process. Some pre-interviews were conducted by phone and others were performed in-person at the time of the site visit.

The actual acceptance testing required one to two days per building. During the testing, the researchers shadowed the contractors and recorded their preparedness for the tests. The judgment of preparedness during the performance of tests was both objective and subjective. Objectively, the researchers were able to evaluate whether the contractor had the equipment required to perform the test. Subjectively, the researchers assessed whether the contractor demonstrated a high, medium or low understanding of the test procedure.

3.2 Findings

The interviews and field evaluation work resulted in a number of qualitative findings indicating barriers to enforcement of acceptance requirements and barriers that prevent contractors from effectively performing the tests. Barriers to enforcement are generally more complex, as they relate to interactions between multiple

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stakeholders with different priorities and responsibilities relating to acceptance requirements. Barriers to successful implementation of tests are more straightforward to address, and in some cases may be resolved through simple updates to testing forms. The key findings are summarized below.

Contractor Interviews

The interviews revealed that contractors were generally aware of the acceptance requirements but were unclear of when they are required. They stated that the design documents must specify the tests or else they would not be performed. Their past experience performing the tests ranged from having performed tests on a regular basis to never having performed any of the tests.

The contractors reported that, overall, the acceptance requirements provide a benefit, but that there are a number of challenges to successful compliance. Tests may not be performed because they incur significant costs that may not be included in bids. When performed, the testing requires a level of judgment that allows a technician to find a “Pass” in most situations, even if a rigid interpretation of the procedure might result in a “Fail.” Where building departments have shown little interest in the testing, there is little incentive to identify problems that may require costly rework. The full set of pre-testing questions and summarized responses from the contractors are provided in Appendix C.

Test Equipment Requirements

Table 7 below shows the equipment required to perform the acceptance tests. The equipment needed for MECH-2A and MECH-4A is the most expensive equipment needed to perform the tests in this study. The duct leakage tester used for MECH-4A is a unique device, and only contractors who typically perform duct leakage tests have easy access to this device. In this study, the mechanical test, adjust, and balance (TAB) contractors had duct leakage testers, whereas the other contractors did not. Depending on the type and quality of the calibrated airflow measuring device needed for MECH-2A, this instrument can also be quite expensive. Again, the TAB contractors typically have easy access to this device.

Table 7: Equipment required for acceptance testing

Form	Test Name	Equipment Required
MECH-2A	Variable or Constant Volume Outdoor Air Acceptance	Calibrated airflow measuring device (hot-wire anemometer or velocity pressure probe)
MECH-3A	Constant Volume, Single-Zone, Unitary AC and Heat Pump	None
MECH-4A	Air Distribution Systems	Duct leakage tester
MECH-5A	Air Economizer Controls	Calibrated temperature probe, Multi-meter, 1.2 kOhm resistor
MECH-7A	Supply Fan Variable Flow Controls	Calibrated differential pressure gauge, Pilot tube, Drill
MECH-9A	Supply Water Temperature Reset Controls	Calibrated temperature sensor
MECH-10A	Hydronic System Variable Flow Controls	Calibrated differential pressure gauge (hydronic manometer)
LTG-3A	Automatic Daylighting Controls Acceptance	Logging light meter, Amp meter, Volt meter, or Power meter
LTG-2A	Occupancy Sensor Acceptance	Light meter, Amp meter, Volt meter, or Power meter
LTG-2A	Manual Daylighting Controls Acceptance	Light meter, Amp meter, Volt meter, or Power meter
LTG-2A	Automatic Time Switch Control Acceptance	Light meter, Amp meter, Volt meter, or Power meter

The TAB contractors participating in this study seemed to have the most sophisticated types of airflow measurement devices, which is to be expected given their need to establish airflows as part of their regular test

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and balance procedures. The installation and start-up technicians had equipment to measure airflow, but it was typically less sophisticated, less expensive, lower quality, and more prone to error in the measurement.

The mechanical service contractor who participated in this study did not have access to airflow measurement equipment or previous familiarity with the test procedures. Service contractors are not typically required to perform acceptance tests, and thus this low preparedness is likely to be typical.

Contractor Suitability for Performing Tests

During the testing, the researchers observed that the mechanical contractors most familiar with the tests were those who performed TAB tasks regularly. These contractors establish the correct airflow in air handler units, VAV boxes and calibrating systems before occupancy. Mechanical installation and start-up technicians were also relatively knowledgeable of the acceptance tests. They are the contractors who turn on the equipment the first time after installation, verify it has been installed properly, and exercise it through various modes of operation. Table 8 below describes in more detail the level of knowledge and experience with the acceptance tests that were demonstrated by each contractor.

Table 8: Contractors' acceptance testing knowledge and experience

Contractor ID	Contractor Type	Preparedness		
		Equipment	Familiarity	Comments
1	Mechanical/TAB	Most/All	Medium	Well suited to perform the tests. Had most or all of the necessary equipment. Familiar with the test procedures. Had attended training sponsored by the CEC, CALBO, and/or SMACNA.
2	Mechanical/TAB	Most/All	High	Well suited to perform the tests. Had most or all of the necessary equipment. Familiar with the test procedures. Sensor calibrations usually occur during TAB so forms can be completed at this time. Had attended training sponsored by the CEC, CALBO, and/or SMACNA.
3	Mechanical/Start-up	Most/All	Medium	Well suited to perform the tests but technician was not very familiar with the tests. Had most or all of the necessary equipment. Not the best suited for verifying airflows as equipment was limited and not very accurate.
4	Mechanical/Start-up	Most/All	Medium	Well suited to perform the tests. Had most or all of the necessary equipment. Familiar with the test procedures. Not the best suited for verifying airflows.
5	Mechanical/Start-up	Most/All	Medium	Well suited to perform the tests. Had most or all of the necessary equipment. Familiar with the test procedures. Not the best suited for verifying airflows.
6	Mechanical/Start-up	Most/All	Medium	Well suited to perform the tests. Had most or all of the necessary equipment. Familiar with the test procedures. Not the best suited for verifying airflows. Had not attended any training. Had received some training from the local college on Title 24, but not acceptance tests specifically.
7	Mechanical/Service	Lacking	Low	Not well suited to perform the tests since technician didn't have much of the necessary equipment. Also completely unfamiliar with the forms and requirements. Had not attended any training.
8	Electrician	All ¹	Medium	Capable of performing the lighting tests but had difficulty following the test procedure. The electrical contractor indicated he didn't have to perform acceptance testing on a regular basis.

¹ The electrician performed only lighting tests and thus equipment preparedness refers only to those lighting tests.

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After completing the tests, the researchers again interviewed the contractors to find if they had encountered any difficulties in performing the tests and to see if they had additional insights on the effectiveness of the tests. At this point, the contractors identified many more difficulties with the tests, including a lack of proper documentation, confusing test language, and unrealistic test conditions. The full set of questions and summarized responses from the post-testing interviews are provided as Appendix D.

The researchers identified many suggested revisions to the test procedures and training opportunities through the debriefing interviews. These suggestions have been incorporated in the recommendations at the conclusion of this report.

Test Results

Evaluating the test results and observing the root cause of failed tests allowed the researchers to identify where test procedures are working well and where they could be improved. Of the 48 tests conducted during this study, the testing contractors reported 19 of the tests as “passed” and 29 tests as “failed,” and these assessments are discussed below. The data presented in Table 9 below summarizes the results for each type of test.

Table 9: Summary table of acceptance tests performed

Form	Test Name	Times Performed	Passes	Fails
MECH-2A	Outdoor Air Acceptance	8	1	7
MECH-3A	Constant Volume, Single-Zone, Unitary AC and Heat Pump	5	2	3
MECH-4A	Air Distribution Systems	3	1	2
MECH-5A	Air Economizer Controls	8	5	3
MECH-7A	Supply Fan Variable Flow Controls	10	7	3
MECH-9A	Supply Water Temperature Reset Controls	2	1	1
MECH-10A	Hydronic System Variable Flow Controls	1	0	1
LTG-3A	Automatic Daylighting Controls Acceptance	7	0	7
LTG-2A	Occupancy Sensor Acceptance, Manual Daylighting Controls Acceptance, and Automatic Time Switch Control Acceptance	3	1	2
OLTG-2A	Outdoor Lighting Shut-off Controls	1	1	0

The share of failures by mode are shown in Figure 3 below. The failure modes are generalized and are not necessarily the root cause of test failure.

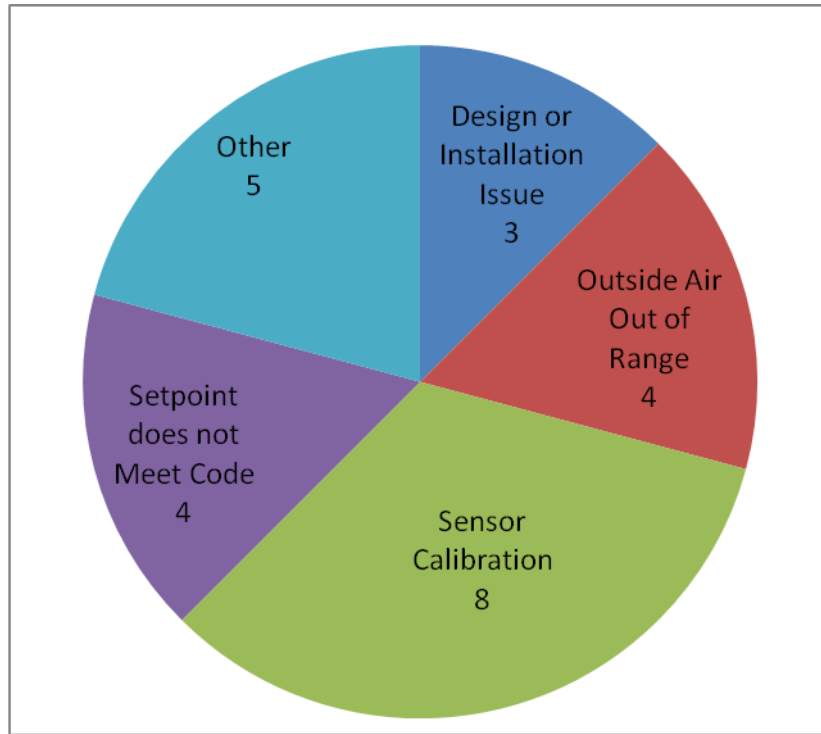


Figure 3: Failure modes of failed acceptance tests

Based on the observations of the tests, the researchers identified which acceptance test failures represented a successful diagnosis of a problem with the building operation and which represented a failure of the test itself. For example, outside air was out of range in one MECH-2A test because a broken damper linkage prevented the outside air damper from properly modulating, which represents a successful diagnosis of a problem. But in another case, the test was failed when outside air was out of range because the air handler was not capable of achieving the *test conditions*, despite the system being capable of satisfying the *code requirement* of providing minimum ventilation. This represents a failure of the test itself. The various root causes of failures and their categorizations as a correct or incorrect diagnoses are shown in Table 10 below.

Table 10: Description of failure modes

Failure Mode	Acceptance Test(s)	Examples of Failure Root Cause(s)	Correct Diagnosis?
Design/Installation Issue	LTG-3A	Photocell sensors installed outside the controlled zone	Yes
		Controlled light fixtures outside of the daylit zone	Yes
Outside Air Out of Range	MECH-2A	Broken damper linkage.	Yes
		Incorrect measurement due to quality of equipment or technician experience. For example, the mechanical start-up technician utilized a less expensive airflow measuring device than the TAB contractor. This device was less accurate, and the technique they used allowed for a significant variation in their measurements.	No
		Equipment unable to achieve the test condition	No
Sensor Calibration	MECH-7A	Duct static pressure sensors used to control supply fan speed out of calibration	Yes
	LTG-3A	Photocell dimming sensors used to dim lighting in daylit zones out of calibration. Sensors were approximately 5 years old and it was indicated they had never worked properly.	Yes

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Failure Mode	Acceptance Test(s)	Examples of Failure Root Cause(s)	Correct Diagnosis?
Setpoint Not Meeting Code	MECH-3A	Economizer lockout temperature and enthalpy do not meet code based on climate zone	Yes
	MECH-5A	Supply fan operation was found to not be continuous as required by code	Yes
Other	MECH-7A	Static pressure setpoint not met at design airflow. This was commonly tested by driving all VAV boxes to full cooling. Doing this always resulted in the fan being unable to maintain the static pressure setpoint so the test will always fail.	No
	MECH-7A, MECH-10A	Stabilization time to reach setpoint exceeded 5 minutes with DDC controls. This time is dependent on the DDC programming and not always achievable.	No

Findings Summary: Barriers due to Test Design

The guidance to the engineers and contractors who specify and perform acceptance tests is largely contained within the Nonresidential Appendices to Title 24 and the Nonresidential Compliance Manual. This guidance includes both the procedures and forms needed to complete tests and submit the results to building officials. Where the forms are unclear or the procedures too complex, confusion and non-compliance may result. Findings related to test and form design are described below.

Exclusion of system types

One of the problems the researchers observed with test forms is that they do not apply to all systems. This can cause confusion, a loss of credibility for the test, and a missed opportunity to ensure system energy efficiency. An example of this is the MECH-5A, which includes a test to ensure that an air handler is not heating during economizer mode. The form does not include a provision to ensure boiler lockout conditions are established or that excessive reheating is prevented while economizing. Without such a provision, testing contractors tended to assume that the test did not apply to systems that have a boiler for hot water reheat at perimeter VAV boxes.

Test conditions mis-matched to best practice building design

Similar problems were found in other test forms. In discussing the full cooling condition, MECH-7A makes no mention of the diversity factor of VAV boxes, which led some technicians to improperly achieve the full cooling condition by driving all VAV boxes to full design airflow. MECH-7A and MECH-10A allow time limits for system stabilization that the field observations suggested were unreasonably short. In these, and other cases, following the test literally would result in a fail, even in a well-designed, code compliant and energy efficient building. Revisions to the forms to correct these deficiencies are discussed in the recommendations.

Complexity

A significant barrier to successful completion of the MECH-7A and MECH-10A acceptance tests is the complexity of specific inspection criteria on the tests. Table 11 below lists the problematic inspection criteria.

Table 11: Acceptance tests and corresponding inspection criteria

Acceptance Test	Construction Inspection Criteria
MECH-7A: Supply Fan VFD Acceptance	The static pressure location, setpoint, and reset control meets the requirements of the 2008 Title 24 Standards Section 144(c)2C.
MECH-10A: Hydronic System Variable Flow Control Acceptance	Pressure sensor location, setpoint, and reset control meets the requirements of Standards section 144(j)6B.

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In every observed MECH-7A and MECH-10A test, the code requirement was not adequately verified. The reasons for this included the difficulty of locating sensors and confusion over the meaning of the inspection criteria. Ensuring that the pressure sensor installation and setpoint meet the criteria are important due to the potential energy impact of the system running at a higher static pressure than necessary.

Several of the acceptance tests, including MECH-2A, MECH-7A, MECH-9A, and MECH-10A, require that a control sensor is either field calibrated or factory calibrated. It was clear from the field surveys that it is generally assumed that sensors come calibrated from the factory. In no case was documentation verified, mainly because it was difficult or impossible to obtain the necessary documentation.

Findings Summary: Test Implementation

During field testing, the researchers observed that whether or not a test actually passed or failed was in some cases open to interpretation by the technician performing the test. This resulted in some measurements being identified as failures by one technician and passes by another technician. In the latter case, a pass was often granted when the technician felt the intent of the test was met. This subjectivity combined with a varying level of expertise among the contractors to result in a high variance in the level of rigor being applied to different buildings.

Acceptance Test Training

The contractors who experienced the least difficulties in consistently applying the test procedures and correctly completing the forms were those who had been exposed to the tests through training, were involved in creating the tests, or had previously performed the tests. Despite many contractors' lack of familiarity with some portion of the tests, only two brought along supporting documentation, such as the 2008 Standards and the Compliance Manual. This suggested to the researchers that the availability of these resources was not well known.

The varying rigor was particularly evident in the contractors' measurements of outside airflow. Unless an accurate method of measuring outside airflow is used, results vary widely and the process lacks credibility. Also, making damper or sensor adjustments based on questionable results may result in equipment being adjusted even further out of intended position or operation. As one of the most experienced and knowledgeable technicians suggested, it would be useful to have a preferred method for measuring airflow and document this method on the test forms. This finding also suggests that a required level of competency and expertise, on par with a TAB contractor, may be necessary to ensure consistent compliance.

Technicians' exposure to training on the acceptance requirements was minimal. Those that indicated they had received training said it was more general to Title 24 requirements and not specific to actual acceptance tests and lacked hands-on learning. Specific training on the acceptance tests was desired by the technicians and would be well received. In addition, training for contractors is critical to increasing compliance with acceptance testing. It was noted that technicians could easily skip important parts of each test that are critical to ensuring proper and efficient system operation.

Coordination and Responsibilities

One of the barriers to completing the tests was contractor lack of familiarity with the HVAC and lighting equipment. Certain tests require manipulating setpoints in equipment controllers. If they were unable to make the necessary adjustments, they either found a work-around that may not test the system effectively or they indicated "NA" (i.e. Not applicable) on the form. One solution that the researchers found to this lack of familiarity was to enlist the assistance of the building operator, the equipment representative, or a controls contractor. Having the controls contractor on site and available to assist throughout the duration of the testing was vital to completing some tests. However, this required significant time and effort. Coordinating between all the parties involved proved to be one of the more significant barriers to completing the acceptance tests.

Another significant barrier is that the Responsible Party for completing the tests is not clearly defined. Each acceptance test includes a Field Technicians Declaration Statement and a Responsible Person's Declaration

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Statement, but neither of these sections defines who should be conducting the tests and including them in their bid. In addition, the responsible parties for performing the acceptance tests are rarely documented on the ENV-1C, MECH-1C and LTG-1C forms. Therefore, it is likely that the contractor who should be performing the acceptance tests didn't include pricing for the tests in the scope of their work and will therefore not be engaged in the process of conducting the tests. To prevent this operating deficiency and avoid any conflict of interest, it may be prudent to have a third party contractor, such as a commissioning agent, be responsible for ensuring completion of the acceptance tests.

4 Recommendations

The findings of this study relate to the effectiveness of the existing compliance process and the challenges for HVAC/lighting/controls contractors in conducting acceptance testing. This project identified multiple barriers and presents recommendations below to promote more effective implementation in the future.

4.1 Recommendations for Improving Compliance

Table 12 below shows the recommendation to remedy each of the barriers to compliance that were found in this study.

Table 12: Recommendations for improving compliance with acceptance requirements

Finding	Recommendation
With limited staff in building departments, acceptance forms receive little to no review.	<ul style="list-style-type: none">• On projects that include commissioning (e.g. commercial buildings complying with CALGreen) require that the Commissioning Authority collect and review the completed acceptance forms.• Share success stories for building departments who have outsourced acceptance testing review to MEP firms; this may be a viable and cost-effective option for other jurisdictions• Educate building owners on the benefits of acceptance testing and code requirements, and encourage them to request and review forms. Compliance would improve if building owners request completed test forms. This is discussed further in section 4.3 Training and Outreach Recommendations.• Building departments might begin by selecting a sample of forms for review. Even reviewing one form for each project could help to raise awareness of the requirements in the building industry.
Inadequate training of building officials and contractors contributes to low compliance.	<ul style="list-style-type: none">• Installers, inspectors, and engineers should participate in joint, interactive training sessions. This helps promote the idea that the cooperation of all parties contributes to effective acceptance testing and code compliance.• Provide targeted training to private sector companies (usually engineering firms) contracted for plans examinations.• Although some interview responses indicated a preference for web-based training over in-person training, it has been observed by Energy Commission staff that previous web-based training received very low attendance. Webinars may still be of benefit, but the root cause – lack of motivation and/or time – would need to be addressed in order to ensure success• Require installation contractors to complete an online training or to read Chapter 10 “Acceptance Requirements” in the Title 24 Nonresidential Compliance Manual and sign a form stating they’ve read it and understand it. Records showing satisfaction of this requirement could be maintained on the CEC website for all approved installing contractors.• Handouts should be created so building inspectors can distribute them to installing contractors as needed. These handouts should cover frequently asked

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Finding	Recommendation
	questions about acceptance testing. Handouts produced by the CEC will provide a greater sense of authority than verbal direction by building officials. These handouts should include key contacts and references (e.g. CEC Energy Hotline).
Stakeholders are unaware of their options for getting help.	<ul style="list-style-type: none"> The CEC's Energy Hotline contact information and hours of operation should be added to each of the acceptance forms, the Nonresidential Appendix NA7, and the Nonresidential Compliance Manual Chapter 10. Investigate utilization rates and awareness levels among building permitting departments for the training resources available on the CEC's website, and determine a plan for increasing awareness and accessibility
Tests are being improperly specified by compliance software contributing to confusion.	<ul style="list-style-type: none"> Communicate these errors to the compliance software developers to ensure any potential software bugs are addressed. Work with them to perform testing on the latest version of each software tool to verify the software specifies the proper tests. Revise the compliance software users' manuals as necessary.
Who bears responsibility for performing the tests is often unclear.	<ul style="list-style-type: none"> The compliance software should require an entry for the Responsible Party before it begins the simulation run. If no entry, software will should not print forms; error should be reported and the missing input should be referenced. On projects that include commissioning (e.g. commercial buildings complying with CALGreen) require the Commissioning Authority to collect and review the completed acceptance forms and specifically check for the Responsible Party. By default, it is recommended that the installing contractor be the Responsible Party, and the software can allow for alternatives to be entered
The number of acceptance test forms complicates the review process for building departments	<ul style="list-style-type: none"> Shorten and consolidate the forms as appropriate. Consider consolidating forms that need to be completed based on system type, eg. packaged units and built up systems. Also, eliminate redundant information on the group of forms that must be completed for every project.

The recommendations in Table 12 are predominantly targeted at improving compliance, but overlap to some degree with recommendations for improving the effectiveness of testing by contractors; for example, reducing the number of acceptance test forms could potentially reduce the challenges for a testing contractor.

4.2 Recommendations for Improving Effectiveness of Testing

All of the acceptance tests and forms that were evaluated have been edited with proposed changes, for consideration by the CEC. A summary of the changes is provided in Appendix E. The edits made to the test forms are designed to provide testing technicians with information on the supporting documentation needed to complete the tests, to clarify the tests to make them easier to understand, to improve effectiveness of the tests, and ultimately to improve compliance rates. The acceptance tests not addressed as part of this study could be evaluated in a similar fashion.

It is recommended to further review testing equipment requirements and test methods and to provide more detailed specifications where equipment and methods could vary significantly. The key example highlighted through this project was measurement of outside airflow, a metric that can have a major impact on a building's energy use.

It is recommended that training and other key reference documents emphasize the coordination aspect for the tester. For example, performing some tests may require a controls contractor on site, to manipulate building controls while the testing contractor observes mechanical equipment behavior.

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Sensor calibration is critical to proper mechanical system operation, and it is recommended to clarify the sensor calibration requirements of acceptance testing. Specifically, if no certificate of factory calibration or documentation of field calibration is available, then the party responsible for performing the necessary field calibration should be identified.

TAB and start-up technicians generally had the required equipment to perform acceptance tests, whereas service contractors are often lacking some specialized equipment. Therefore, it is recommended that the TAB contractor, start-up contractor, or installing contractor be required to perform the more complex HVAC tests.

It is recommended that the California State Licensing Board consider incorporating Title 24-related elements into certification examinations for HVAC contractors. To maximize the impact of such an effort, recertification of current HVAC contractors could be required, although may need to be rolled out over a long period to minimize any economic impacts.

4.3 Training and Outreach Recommendations

Successful implementation of Title 24 requires multiple stakeholders to be informed, trained, and motivated: Building permitting officials, building owners, engineering firms/architects, and contractors. Each of these stakeholder groups has differing needs, and should be targeted differently. Recommendations for each of these stakeholder groups are summarized below.

Building Permitting Officials

Comprehensive web-based training materials are already available through the CEC website, and hands-on training has been developed by the California Commissioning Collaborative. Building officials currently have the best resources of the four stakeholder groups. Recommended outreach focuses on enhancing the visibility of those resources and promoting their use by:

- Highlighting the success of jurisdictions with high compliance rates, describing the practices that contribute to the high compliance
- Highlighting successful cases where a permitting department has outsourced the acceptance testing review tasks, as a cost-effective response to reduced department budgets

Building Owners

It is recommended to create targeted outreach materials for building owners to improve their awareness of the acceptance testing requirements, illustrate the long term benefits of effective acceptance testing, and also to clarify the process. These outreach materials could include:

- Case study materials (or even hypothetical examples) to indicate the potential long term cost of running a building with noncompliant equipment
- Graphical flow charts, or perhaps short animations, to illustrate where the owner has influence in ensuring that acceptance testing is specified in the construction documents, and also in checking that testing has been completed prior to occupancy

Engineering Firms

Outreach to engineering firms and architects should focus on clarifying the compliance process, to ensure that acceptance requirements are appropriately specified in construction documents. A specific outcome that this outreach could target is ensuring that construction documents identify the Responsible Party for performing acceptance testing.

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Contractors

Recommended outreach for contractors includes training, support, and efforts to overcome motivational barriers. Outreach to TAB, start-up, and installation contractors could include:

- Provide practical hands on training – perhaps supported by web-based videos – to illustrate in detail how tests should be performed
- Develop marketing materials that contractors can include with their bids when acceptance testing is required. Officially-endorsed documentation would encourage owners to look favorably on those bids and would help highlight situations where a low bid competitor has omitted acceptance testing
- Develop a case study on a contracting firm who has successfully incorporated Title 24 acceptance testing as a core strategy to distinguish their firm in the marketplace. This would encourage other contractors to view acceptance testing as a marketing tool

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Appendix A: Phone Interview Instruments

Building Department Phone Interview Instrument

Contact Name	
City Name	
Phone Number	
Interview Conducted By	
Date of Interview	

Hi, my name is _____ with PECL and I'm calling on behalf of the California Energy Commission. The project team are conducting a study to characterize current practice of Title 24 acceptance requirements. Speaking with you will help us develop recommendations for improving these code requirements. Is this a convenient time to talk for fifteen minutes? If not, when would be a better time? *This is the part of Title 24 where the HVAC and lighting installing contractors perform functional testing to exercise the equipment and verify that it works properly before the certificate of occupancy is granted.* **Your responses are completely anonymous; the project team will report the details in aggregate from multiple building departments with nothing to identify particular departments or buildings.**

1. How familiar are you with the acceptance requirements in the energy code for certain HVAC and lighting equipment? (Nonresidential Appendix NA7 in Title 24)
2. Are you aware of the new tests that were required when the 2008 standards became effective on January 1 this year?
3. If yes, how did you first learn about these new tests?
4. What is your understanding of the purpose of the acceptance requirements?
5. Do you find the acceptance requirements clear and easy to understand? If not, what is not clear?
6. Do you find the acceptance testing forms clear and easy to follow? If not, what is not clear?
7. How many projects with acceptance testing do you process each week or each month?
8. How many of these have problems that require additional work, for example missing or incomplete forms?
9. What are the most common problems?
10. Do you require completed acceptance testing documentation before issuing a certificate of occupancy?
11. If you do collect the documentation, do you review the content? What do you review?
12. How long do you hold onto the forms before discarding them?
13. What tasks are involved with processing the acceptance testing portion of a project?
14. How much time is required to process the acceptance testing portion of a project?
15. Do your inspectors verify any of the acceptance testing results onsite?

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16. Do you have any reason to believe some contractors are not performing the required tests? For example not submitting the forms to you or submitting with false data.
17. Have you or any of your co-workers received training on the acceptance requirements? If not, are you aware of any upcoming training opportunities?
18. What resources does your department rely on to train staff on understanding and enforcing the acceptance requirements?
19. Would you prefer in-person training or print/online materials?
20. *(For 4-6 building departments that have processed many acceptance forms, ask this.)* In an attempt to better understand and appreciate the challenges your department faces, I'd like to visit your office to review a few plan sets for more details. For example, this would help me understand how compliance through permit review compares with compliance through field inspections with respect to particular acceptance tests. Can the project team make an appointment for two weeks from today? Does this allow enough time for your staff to pull four or five plan sets with the permit records and acceptance forms? I prefer buildings from 2008 to 2009 and include a range of commercial building types and sizes.

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Contractor Phone Interview Instrument

Contact Name	
Contact Company Name	
Interview Conducted By	
Date of Interview	

Hi, my name is _____ with PEI and I'm calling on behalf of the California Energy Commission. The project team are conducting a study to characterize current practice with acceptance requirements. This is the part of Title 24 where the HVAC and lighting installing contractors perform functional testing to exercise the equipment and verify that it works properly before the certificate of occupancy is granted. Speaking with you will help us develop recommendations for improving these code requirements. Your responses are completely anonymous; the project team will report the details in aggregate from multiple companies with nothing to identify particular people or companies. Is this a convenient time to talk for fifteen minutes? If not, when would be a better time?

1. Are you familiar with the acceptance requirements in the energy code for certain HVAC and lighting equipment? (Nonresidential Appendix NA7 in Title 24)
2. What is your experience with conducting acceptance tests?
3. Are you aware of the new tests that were required when the 2008 standards became effective on January 1 this year?
4. If yes, how did you first learn about these new tests?
5. What is your understanding of the purpose of the acceptance requirements?
6. Do you find the acceptance requirements clear and easy to understand? If not, what is not clear?
7. Do you find the acceptance testing forms clear and easy to follow? If not, what is not clear?
8. How often do you perform acceptance testing?
9. Which of the following tests have you done?

Test	Yes	No
NA7.4 Building Envelope		
Fenestration		
NA7.5 Mechanical Systems		
Outdoor Air		
Constant Volume, Single Zone, Unitary Air Conditioners and Heat Pumps		
Air Distribution Systems		
Air Economizer Controls		
Demand Control Ventilation (DCV) Systems		
Supply Fan Variable Flow Controls		
Valve Leakage Test		

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Test	Yes	No
Supply Water Temperature Reset		
Hydronic System Variable Flow Controls		
Automatic Demand Shed Control Acceptance		
Fault Detection and Diagnostics (FDD) for Packaged Direct-Expansion Units		
Automatic FDD for air handling units and zone terminal units		
Distributed Energy Storage DX AC Systems Acceptance Tests		
Thermal Energy Storage (TES) Systems		
NA7.6 Indoor Lighting Controls Systems		
Automatic Daylighting Controls		
Occupancy Sensor		
Manual Daylighting Controls		
Automatic Time Switch Control		
NA7.7 Outdoor Lighting		
Outdoor Motion Sensor		
Outdoor Lighting Shut-off Controls		

10. In general, how often do the tests fail the first time?
11. What are the most common problems (why the test fails)?
12. Do you have the test equipment required to perform the tests? If not, what do you need?
13. How much time is required to conduct the acceptance tests?
14. How do you factor in the cost to perform acceptance tests into your bid cost? Typically, what is the additional cost to perform acceptance tests?
15. Do the building departments require completed acceptance testing documentation before issuing a certificate of occupancy?
16. After you submit the acceptance documents to the building departments, do they ever contact you again needing anything else?
17. Do the inspectors verify any of the acceptance testing results onsite?
18. What is your or your company's attitude about the acceptance requirements? (not beneficial to owner; relatively beneficial; highly beneficial; leads to more work/money; indifferent)
19. Have you or anyone else in your company received training on the acceptance requirements?
20. What was the training?
21. Would you prefer in-person training or print/online materials?

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Building Owner Phone Interview Instrument

Contact Name	
Contact Company Name	
Interview Conducted By	
Date of Interview	

Hi, my name is _____ with PECO and I'm calling on behalf of the California Energy Commission. The project team are conducting a study to characterize current practice with acceptance requirements. This is the part of Title 24 where the HVAC and lighting installing contractors perform functional testing to exercise the equipment and verify that it works properly before the certificate of occupancy is granted. Speaking with you will help us develop recommendations for improving these code requirements. Your responses are completely anonymous; the project team will report the details in aggregate from multiple companies with nothing to identify particular people, companies, or buildings. Is this a convenient time to talk for fifteen minutes? If not, when would be a better time?

1. Are you familiar with the acceptance requirements in the state energy code for certain HVAC and lighting equipment?
2. Are you aware of the new tests that were required when the 2008 standards became effective on January 1 this year?
3. If yes... How did you first learn about these new tests?
4. What is your understanding of the purpose of the acceptance requirements?
5. How many projects with acceptance testing have you been involved in?
6. In your experience, what is the additional cost for conducting acceptance tests?
7. What value do you see in requiring your contractors to perform this testing?
8. What benefits have you seen from having these acceptance tests performed? *(If they haven't had any testing done, ask the following question)* What potential benefits do you foresee from requiring acceptance testing?
9. What buildings are these? (type, location)
10. Do you know if any of the tests failed the first time and required a contractor to repair problems with HVAC or lighting equipment?
11. Do you remember what the problems were?
12. Do you review the acceptance testing documentation from your contractors?
13. Do you have any reason to believe some contractors are not performing the required tests? For example not performing the tests or submitting with false data.
14. Do you have any new projects in development?
15. When do you expect completion of these projects?
16. Would you be willing to allow me to accompany your contractor to observe the acceptance testing?

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Design Engineer Phone Interview Instrument

Contact Name	
Contact Company Name	
Phone number	
Interview Conducted By	
Date of Interview	

Hi, my name is _____ with PEI and I'm calling on behalf of the California Energy Commission. The project team are doing a study on current practices around Title 24 acceptance requirements. This is the part of Title 24 where the HVAC and lighting contractors test and verify that the equipment works properly before the certificate of occupancy is granted. We're hoping to conduct a 15 minute interview with you in the next couple weeks. Speaking with you will help us develop recommendations for improving code. Your responses are completely anonymous; the project team will report the details in aggregate from multiple companies with nothing to identify particular people or companies. If not, when would be a better time?

1. Are you familiar with the acceptance requirements in Title 24 for certain HVAC and lighting equipment? (Nonresidential Appendix NA7 in Title 24)
2. What is your experience with conducting acceptance tests?
3. Are you aware of the new tests that were required when the 2008 standards became effective on January 1 this year?
4. If yes, how did you first learn about these new tests?
5. Who is responsible for determining which tests are needed for a given project?
6. Who determines which testing forms need to be submitted to the building department?
7. Do you include the applicable acceptance testing forms in the construction documents? Job specifications? Neither?
8. Do you find the acceptance requirements clear and easy to understand? If not, what is not clear?
9. Do you conduct the acceptance testing yourself or rely on another trade, such as the installing contractor?
 - IF ENGINEER CONDUCTS TESTS:
 - a. How often do you perform acceptance testing?
 - b. How do you factor in the cost to perform acceptance tests into your bid cost?
 - c. Typically, what is the additional cost to perform acceptance tests?
 - d. Do you find the acceptance testing forms clear and easy to follow? If not, what is not clear?
 - IF ANOTHER TRADE CONDUCTS TESTS:
 - a. Do you observe the acceptance testing?
 - b. Do you ask them to include the cost to perform acceptance tests into their bid cost?
10. Which of the following tests have you done/observed?

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Test	Yes	No
NA7.4 Building Envelope		
Fenestration		
NA7.5 Mechanical Systems		
Outdoor Air		
Constant Volume, Single Zone, Unitary Air Conditioners and Heat Pumps		
Air Distribution Systems		
Air Economizer Controls		
Demand Control Ventilation (DCV) Systems		
Supply Fan Variable Flow Controls		
Valve Leakage Test		
Supply Water Temperature Reset		
Hydronic System Variable Flow Controls		
Automatic Demand Shed Control Acceptance		
Fault Detection and Diagnostics (FDD) for Packaged Direct-Expansion Units		
Automatic FDD for air handling units and zone terminal units		
Distributed Energy Storage DX AC Systems Acceptance Tests		
Thermal Energy Storage (TES) Systems		
NA7.6 Indoor Lighting Controls Systems		
Automatic Daylighting Controls		
Occupancy Sensor		
Manual Daylighting Controls		
Automatic Time Switch Control		
NA7.7 Outdoor Lighting		
Outdoor Motion Sensor		
Outdoor Lighting Shut-off Controls		

11. In general, how often do the tests fail the first time?
12. What are the most common problems (why the test fails)?
13. Do the building departments require completed acceptance testing documentation before issuing a certificate of occupancy?
14. After you submit the acceptance documents to the building departments, do they ever contact you again needing anything else?
15. What is your or your company's attitude about the acceptance requirements? (not beneficial to owner; relatively beneficial; highly beneficial; leads to more work/money; indifferent)
16. Have you or anyone else in your company received training on the acceptance requirements?
17. What was the training?

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- 18. Would you prefer in-person training or print/online materials?
- 19. I plan to also interview a number of installing contractors to learn about their perspective. Can you recommend anyone in particular I could contact? *(If yes, ask for his email address so you can send him an email with your contact information).* (Contractor name and company is sufficient; the project team can look up their contact info)

Name	Company Name	Phone Number

Appendix B: Phone Interview Summaries

Building Department Phone Interview Summaries

Interview	Understanding			Problems		Process						Training Received		Training Preference	
	Familiarity	Purpose	Clarity	Common Problems	% rework required	Required for CFO?	Reviews ?	# per month	Time (hrs)	Discard Forms?	Onsite verification	Training Received	Resources used	In-person	Online/printed Materials
1	Fairly	Document equip testing, results and compliance	Confusing; not easy to understand	N/A	N/A	Yes	Yes	3 to 4 (NC)	2	No	Yes	Yes	N/A	Yes	No
2	Fairly	Document the project	Better than 2005 version	Incorrect/inc complete sections	33%	Yes	Yes	20 (mostly Tis)	N/A	No	Unknown	Yes	CEC website	Yes	Yes
3	Unfamiliar	Unfamiliar	Confusing; not easy to understand	N/A	N/A	No	No	N/A	N/A	N/A	No	No	N/A	N/A	N/A
4	Above Average	Support HERs raters	Confusing; not easy to understand	N/A	N/A	Yes	Yes	5 max	0.75	No	No	Yes	Local CEC chapter; PG&E sponsored trainings	Yes	Yes
5	Fairly	Equip is functional, meets design intent and compliance	Confusing; not easy to understand	N/A	N/A	Yes (Now)	yes (now)	1	N/A	No	N/A	Yes	Utility sponsored trainings	Yes	Yes
6	Yes	Equip is functional, meets design intent and compliance	Better than 2005 version	Incorrect forms used; Unfamiliarity of industry with forms	>80%	Yes	Yes	0	15 min/form	No	No	Yes	Call CEC	Yes	Yes
7	Knows they exist	Put responsibility on the installing contractor to ensure equip is installed and functioning.	Forms are clear, the process isn't	Incorrect forms used; Unfamiliarity of industry with forms	>50%	Yes; TCO will be issued with a promise that forms are to be submitted.	Yes	6 max	1	No, forms go to bldg owner	No	Yes	SMACNA, CEC, other CA inspectors	Yes	Yes
8	Fairly	Compliance	Confusing; not easy to understand	Incorrect forms used; Unfamiliarity of industry with forms	>50%	Yes	Yes	8 max	1	No	Yes	Yes	Online webinars; CEC 1-800 number	Yes	No

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Contractor Phone Interview Summaries

Interview	Understanding					
	Familiarity	Aware of 2008 Title 24 Standards?	How did you learn about 2008 standards?	Who executes tests?	Purpose	Forms are easy to understand?
1	None	No	N/A	CxA	N/A	N/A
2	None	No	N/A	Electrical Engineer	Confirm energy efficiency techniques have been used.	N/A
3	Yes	Yes, but not familiar	N/A	Installing contractor	Verify installation meets design intent & energy code	For the most part
4	Little	Yes	N/A	They do (TAB contractor)	N/A	Yes, very clear
5	Yes	Yes	He was involved with the CEC writing the forms.	He does (TAB contractor)	N/A	Yes, very clear. Forms are improved over 2005 forms.
6	Yes	Yes	Through various jobs and also at school. He is certified through NEBB and TABB. He is also an instructor for the local Union.	He does. I didn't ask him specifically who was the best person to conduct the testing.	N/A	Not always. Wording is hard to follow. No feedback from the building dept so he assumes he's doing them correctly.
7	Yes	No	N/A	The TAB contractor should be doing the tests. Although he said he performs more fire and life safety testing and not much acceptance testing.		Yes, but the engineer had to assist to ensure the tests passed.
8	Yes	No	N/A	He does.	Save energy and keep contractors honest.	Yes, for the most part.
9	Yes	Yes somewhat.	In college. He took the Non Residential and Residential compliance through the City of San Bernadino. He wasn't required to perform the tests until April of 2010 in Irvine.	He does. But he is part of the start up department. He thought it was reasonable that the start up group be responsible for conducting the tests.	He didn't specifically answer this question.	Somewhat. There are some confusing parts. He gets many questions from his techs that need clarification on the forms.
10	None	No	N/A	He felt the commissioning agent was likely best suited to conduct the tests. He was part of the service department and therefore doesn't see the forms. A more senior level person would have to conduct the tests because of the complexity of the tests.	No answer	N/A. He doesn't have any experience with the forms.

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Contractor Phone Interview Summaries (continued)

Interview	Process			
	Acceptance Forms required for CFO?	How often do you perform tests?	Acceptance testing cost included in bid?	Inspector present for testing
1	No	N/A	No	N/A
2	N/A	N/A	No	N/A
3	Unknown	Very Often. Part of equipment startup	Yes	Yes
4	Sacramento yes, other areas no	Didn't answer	Now they do, before they didn't	Didn't answer. Got the impression no.
5	More common lately, especially in the Sacramento area. Less so in surrounding areas.	No answer	Not always. Not all contractors are including this in their bid so to be competitive they sometimes don't include it.	He didn't answer this. Although he said they are asking for the forms more frequently now.
6	Yes, he said they require a copy of the balancing report.	Recently every couple of months	Less than 10% include acceptance testing in their bids.	No. They just require the forms.
7	In Irvine yes. Other counties didn't require them.	Not often. He's been a TAB contractor for 20 plus years and has only performed these tests twice in the past 6 months. He thinks they're becoming more common.	In Irvine county yes, but not in other counties because they don't require the tests.	An inspector observed him testing outside air once, but that's it. Not recently.
8	In Orange County yes, others not often.	Not very often.	Not sure	No.
9	Yes.	More commonly lately, since April 2010. Since then he's been performing them on a regular basis. He currently is working on two jobs that require the forms.	He didn't know.	Never
10	No.	Never.	No idea.	Never.

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Contractor Phone Interview Summaries (continued)

Interview	Issues		Training		Training Preference		Additional comments
	How often tests fail first time?	What are the common issues?	Training Received?	Resources used?	In-person	Online/printed Materials	
1	50%	Controls & missing components	No	N/A	No	Yes	They factor in the cost of the Cx agent's functional performance testing, which typically doubles the required labor time.
2	Not very often	N/A	No	N/A	No	Yes	[Title 24 acceptance testing] is the responsibility of the Electrical Engineer to perform the acceptance testing, not the EC. The EC will have a technician available to address wiring or other electrical-related installation issues.
3	<50%	misinstallation & incorrect equipment	Yes	SMUD Training	Yes	No	The cost to perform acceptance testing is factored into the bid cost based on past experience and complexity of the system. Typically, this is about 3.5% of the total bid cost (can be higher or lower depending).
4	No answer	No answer	No. Only self training	Forms and supporting documentation	Yes	No	Technician suggested he was 'very' familiar with the forms, but observation during testing showed he seemed to be less familiar with the tests than he represented. As a TAB contractor he seemed able to understand the procedures and intent of the forms.
5	No answer	N/A	Yes	SMACNA. It was geared more for building inspectors	Yes, it should offer hands on training, more focused on HVAC units. There should be some type of a certification for techs on each test, not just HERS.	No	He was one of the more experienced techs with acceptance testing. As a TAB contractor he had all the tools necessary and was well suited to perform the tests.
6	50% of the time.	Measuring outside air accurately is difficult due to leaks. Another issue is with controls. Bugs in the controls are sometimes not resolved.	Received training through NEBB. Although it wasn't very complete.	Limited reference materials	Yes! He definitely prefers in person and hands on training.	No	He felt requiring these tests is good practice because otherwise system commissioning/functional testing like this wouldn't get done. Everyone wants to do a job as cheaply as possible.
7	Never.	N/A	He has received indoor air quality testing using SMACNA guide, but no acceptance testing training.	N/A	No	Yes	He has limited experience with acceptance tests. He recalled an instance where the tenant was eager to move in so the engineer assisted with performing the tests so they passed. He felt his company has a positive attitude toward acceptance testing in general. It would lead to more work.
8	20% of the time	Related to controls, programming, and sequencing. Not being commissioned is an issue that results in problems.	No	N/A	Yes	No	When he first saw the tests he wanted to throw them out, but then saw the potential of the tests to save energy and keep contractors honest. He thinks there are lots of shabby contractors out there. Ultimately the tests ensure the customer gets what he/she pays for.
9	Not often. If he marks NA on the form it won't fail.	Usually the tech failed to understand the question. He mentioned the test is only a minimum requirement so there's really no reason for it to fail.	He received training about Title 24 requirements in general, not specifically acceptance testing training. He took an 18 week class that covered a lot of material, but nothing about what is actually implemented in the field.	College	Yes	No	He emphasized that if the applicable tests that need to be performed on a job are not indicated on the plans they won't get included in the bid or performed. It's up to the designer to get them into the plans.
10	N/A	N/A	None	N/A	No	Yes. He prefers on line training since he's an experienced technician. He felt more junior level techs would prefer in person training.	He felt the commissioning agent is best suited to conduct the acceptance tests. He also mentioned the tests were pretty general and not very applicable to all buildings. The building we tested had multiple pieces of equipment and the test didn't indicate how to conduct the test on multiple pieces of equipment.

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Building Owner Phone Interview Summaries

Interview	Understanding					Process			
	Familiarity	Aware of 2008 Title 24 Standards	How did you learn about 2008 standards?	Purpose	How many projects have you been involved with that required acceptance testing?	What is the additional cost?	What value do you see in requiring contractors to perform the acceptance tests?	What benefits have you seen specifically from having the acceptance tests performed?	What are the building types?
1	Yes, he is familiar with the tests.	Not specifically. They recently started to require these tests from their contractors.	Through the contractors they work with.	To ensure compliance with the code.	Perhaps six. All this year.	A few thousand dollars.	There is value there. He mentioned that some of the issues we caught during our field work were consistent with what they found during their retrocommissioning process.	He couldn't specifically name any.	Low rise, two and three story.
2	Yes	Yes, but only a few of the new tests.	Read Title 24, CEP. He's an architect and needs to be familiar with Title 24.	To ensure minimum conformane to Title 24.	3 for the city since 2005 Title 24.	None. It's included in the cost for LEED, which they do on all projects.	Not much benefit. There isn't third party testing. LEED requires 3rd party which is more effective.	It gets into the bid documents so the contractor can price it into the bid.	No answer
3	Yes	Not specifically. They recently started to require these tests from their contractors.	Through architects during TI's	Help ensure the building meets Title 24 requirements.	None	NA	Plenty of value! Definitely a valuable process.	Potential benefits include improved efficiency, and ensuring you get what you pay for. Also ensuring the contractor follows Title 24.	NA

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Building Owner Phone Interview Summaries (continued)

Interview	Issues				Training		Training Preference		Additional Comments
	How often tests fail first time?	What are the common issues?	Do you review the acceptance testing documentation from your contractors?	Do you have any reason to believe some contractors are not performing the required tests?	Training Received?	Resources used?	In-person	Online/printed Materials	
1	Couldn't say. Someone in the field oversees the tests and handles this.	NA	They are starting to. They'll file in the project folder.	Not really. They require it of the contractor and are going to include it into their (owner's) specification.	No, but he'd like to see his techs get training.		Yes	Yes	He was in favor of providing training to his techs. He had a positive attitude about performing acceptance tests on all their new projects. I didn't sense any opposition to this requirement.
2	Sometimes	100% fresh air full-time, even during heating.	No, he leaves it up to the BD's.	Not on our projects due to someone else watching. An engineer on staff with the city verifies quality work/testing by the contractors.	NA	NA	NA	NA	
3	No	NA	No.	NA	NA	NA	NA	NA	

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Design Engineer Phone Interview Summaries

Interview	Understanding			Responsibility			
	Familiarity	Aware of 2008 Title 24 Standards	How did you learn about 2008 standards?	Who determines needed tests?	Are testing forms included in the construction documents or job spec?	Who determines which forms need to be submitted?	Who executes tests?
1	Yes	Yes	When generating requirements for a recent project	Project Engineer	Neither	Installing contractor	Installing contractor
2	Yes for HVAC	Yes	Specialty Title 24 consultant	Project Engineer	Neither	Title 24 specialty consultant	Installing contractor
3	Yes for HVAC	Yes	EnergyPro & CEC	Project Engineer	Neither	Whoever is responsible for performing the test.	Installing contractor
4	Yes	No	N/A	Project Engineer	Neither, but refers to them in TAB or Cx spec.	Whoever is responsible for performing the test.	Installing contractor
5	Yes	Yes	SDG&E Seminar	Design Engineer	Neither	Design Engineer	Installing contractor
6	Aware, but not familiar	Yes	Co-workers attended SMUD seminar	Project Engineer	Only the acceptance requirements are included on CDs.	Whoever performs the Title 24 energy calculations	Installing contractor
7	Yes for HVAC	Yes	CEC	Project Engineer	In the CDs	Project Engineer	Installing contractor

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Design Engineer Phone Interview Summaries (continued)

	Understanding		Process			
Interview	Requirements are easy to understand?	Forms are easy to understand?	Acceptance Forms required for CFO?	Designer Observes tests?	Designer Conducts Tests?	Require cost from Installers?
1	Yes	N/A	Unknown	No	No	Yes
2	No. Conflict b/w T24 and Mech	N/A	Yes	No	No	No
3	No. Poorly written and difficult to understand.	N/A	No	No	No	Yes
4	No. Difficult to understand who conducts tests	N/A	Unknown	No	No	Yes
5	Yes	N/A	Yes	No	No	No
6	No. Hard to determine which forms apply to a project.	N/A	Unknown	No	No	Yes
7	No. Confusion regarding interpretation.	No. Confusion regarding interpretation.	Yes	No	No	Yes

Appendix C: Contractor Pre-Test Interview Questions and Responses

Question	Contractor Response Summary
<p>Are you familiar with the acceptance requirements in the energy code for certain HVAC and lighting equipment? (Nonresidential Appendix NA7 in Title 24).</p>	<p>Generally the contractors indicated they had heard of the requirements, although there was uncertainty as to when the tests were required.</p> <p>One contractor indicated it would be helpful if there was a reference manual to assist with the tests. He was obviously unfamiliar with the 2008 Nonresidential Compliance Manual. The general understanding was that the tests weren't required or at least enforced until recently.</p> <p>One contractor who had been aware of the acceptance tests since 2005 was an exception. He serves on a committee for the CEC and provided input to the development of the acceptance testing forms.</p>
<p>Are you aware of the new tests that were required when the 2008 standards became effective on January 1 this year? If yes, how did you first learn about these new tests?</p>	<p>Most of the contractors were familiar with acceptance testing requirements beginning in January 2010 but were unaware that they had been required since the 2005 code became effective. Some indicated they had learned of the testing requirements through school or classes they were taking through the union.</p> <p>One TAB contractor who knew of the requirements since 2008 was an exception since he had been involved with the CEC and provided input to acceptance testing requirements. He was the only contractor who was aware of any specific differences between 2005 and 2008 versions of acceptance testing requirements.</p>
<p>What is your experience with conducting acceptance tests?</p>	<p>One of the contractors interviewed had significant knowledge about acceptance testing requirements and had conducted several of the tests since they became required.</p> <p>A majority of the other contractors indicated they had some exposure to the tests, either through a class or actually performing the tests, but this usually consisted of only a few of the tests.</p> <p>One contractor was completely unfamiliar with the tests.</p>
<p>Do you find the acceptance requirements clear and easy to understand? If not, what is not clear?</p>	<p>The answer to this question was typically yes, but it was clear after performing the tests that the contractor was not clear about when the tests need to be performed.</p> <p>Contractors rely on the design documents to determine what tests and forms are necessary. If the drawings don't show that the forms are necessary they don't get performed.</p> <p>It was understood that identifying the specific tests to perform is the responsibility of the engineer.</p>
<p>Do you find the acceptance testing forms clear and easy to follow? If not, what is not clear.</p>	<p>Most contractors answered yes to this question. But it was clear after performing the tests that there were many examples of the tests not being clear and resulting in confusion by the contractor. It appeared that the contractor prepared for the field survey by reviewing the forms and felt they were pretty clear.</p>

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Question	Contractor Response Summary
How often do you perform acceptance testing?	<p>Most indicated they have been performing the tests more often recently, primarily since early 2010.</p> <p>One contractor indicated they perform them on most jobs and he has become quite familiar with the tests.</p> <p>A majority of the other contractors indicated they perform a few tests per month and have since early 2010.</p> <p>One contractor had never performed the tests.</p>
Which of the following tests have you done?	<p>The only tests contractors indicated they have performed are MECH-2A, MECH-3A, MECH-5A, MECH-7A, and LTG-2A.</p>
In general, how often do the tests fail the first time?	<p>Most of the contractors indicated the tests don't fail and they typically pass.</p> <p>In addition, they suggested it was easy to get them to pass when they otherwise may fail. For example, by marking "NA" on a question they technically pass.</p> <p>There is room for interpretation by the technician on the test.</p> <p>One contractor indicated the tests pass the first time 20% of the time, but it appeared they would resolve the issues before submitting the forms to the building department. This is of course the preferred course of action; otherwise the building is not allowed to receive the Certificate of Occupancy.</p>
What are the most common problems (why the test fails)?	<p>Tests sometimes fail because equipment wasn't set up properly.</p> <p>Jobs are being priced so competitively that the quality of installation and startup is poor.</p> <p>Other common failure modes were indicated as problems with controls, controls sequences, and lack of commissioning.</p> <p>Limitations of the equipment was indicated as a cause for failure, such as outside air not being able to vary with supply air of a VAV system.</p>
Do you have the test equipment required to perform the tests? If not, what do you need?	<p>Most of the contractors said they had all or almost all of the required equipment.</p> <p>One of the service contractors said he had limited equipment and purchased a calibrated pressure gauge the day before the test.</p> <p>The TAB contractors typically had the most equipment.</p> <p>Only contractors that performed duct leakage testing or HERS testing had a duct leakage tester.</p> <p>It was indicated that the equipment is expensive and therefore cost prohibitive for some of the contractors.</p>
How much time is required to perform the tests?	<p>The answers varied from a few hours to 25% of the total time on a job, which would be considered significant.</p> <p>One contractor suggested the time it takes to complete the tests is the amount of time it takes to fill them out and sign them.</p> <p>(This particular technician conducted the test quickly and missed significant content in the tests.)</p>
Do the building departments require completed acceptance testing documentation before issuing a certificate of occupancy?	<p>The contractors indicated that building departments in certain jurisdictions request completed acceptance tests.</p> <p>The two cities that required the forms are Sacramento and Irvine.</p> <p>Contractors indicated there was low or no enforcement in the other cities where they performed work.</p>

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Question	Contractor Response Summary
After you submit the acceptance documents to the building departments, do they ever contact you again needing anything else	Contractors answered no. One contractor indicated if a form is incomplete the city kicked it back but generally the answer to this question was overwhelmingly no.
If you would use an alternate procedure, describe why. For example, it is faster, easier, requires no specialized test equipment, and/or results in a more effective test.	Equipment start-up documentation was mentioned as an alternative to performing acceptance tests. Contractors typically have standardized start-up documentation based on equipment type that they use to functionally test equipment. NEBB (National Environmental Balancing Bureau) and TABB (Testing Adjusting and Balancing Bureau) forms are used by Test, Adjust, & Balance (TAB) contractors. In general, the contractors liked the acceptance forms and thought they were a combination of TAB and equipment startup documentation
Do you typically include performing acceptance tests in your scope when preparing a bid?	Three contractors indicated they include performing acceptance testing into their bid. It was mentioned that to remain competitive in the bidding process acceptance testing would only be included if it was required or other contractors were including it. Unless it was indicated on the design documents that acceptance testing was required it typically isn't included in the bid. Including it in the bid is more common now. One of the more experienced techs suggested that the cover sheet of the form that states "I certify under penalty of perjury" is effective at ensuring the tests are included in the scope of work and filled out properly.
Is the additional cost of performing acceptance tests significant in your opinion?	Most of the contractors felt the added cost of performing the tests was significant. For one reason, if a problem is found performing the tests, correcting the deficiency or fault may incur an expense that would be the responsibility of the contractor conducting the test. This could be a disincentive to finding and reporting failures. Although, the benefits of the tests are they add credibility to meeting code requirements. Most felt the additional cost was significant mainly because of the time involved in performing the tests. One contractor felt the only additional time was literally filling out the forms and signing them. It was generally felt that any additional cost can be significant in a competitive bidding process. It could impact whether a job is awarded or not.
In your opinion what percent of contractors are currently including acceptance testing in their bids and performing the tests?	This depends on the jurisdiction. In high compliance rate districts, 80% or more are including acceptance tests in their bids. In other jurisdictions it is 0%. All but one contractor felt it was very low.
In your opinion what percent of contractors are currently performing acceptance testing as an afterthought, i.e. not included in bid but scrambling to comply with Title 24?	Not all contractors answered this question, but one who did suggested all contractors are currently performing acceptance testing as an afterthought.
Do the inspectors verify any of the acceptance testing results onsite?	Most felt they never verify results on site. One answered yes and indicated it was to verify an airflow requirement.

Title 24 Acceptance Testing Requirements and Effectiveness

Question	Contractor Response Summary
What is your or your company's attitude about the acceptance requirements? (not beneficial to owner, relatively beneficial, highly beneficial, leads to more work/money, indifferent).	All companies were supportive of the tests. They felt it leads to more work and adds credibility to their work. The general feeling was there is benefit to performing the tests, but unless they're enforced and everyone does them, they may not perform them in order to remain competitive in bidding.

Appendix D: Post-Test Interview Questions and Responses

Question	Contractor Response Summary
<p>Were there any problems completing the acceptance tests? If so, what was the problem and how was it resolved?</p>	<p>Problems found during the tests included broken equipment, sequences not functioning properly, and sensors out of calibration.</p> <p>Problems conducting the tests included lack of proper documentation (i.e. design documents, standards manual, compliance manual), confusing test language, building occupancy that prevented tests in certain areas from being performed, and difficulties accurately measuring outside air.</p> <p>A problem identified by multiple contractors was found while performing MECH-7A, Supply Fan VFD Acceptance. The test required driving all VAV boxes to design airflow. If this was interpreted as max airflow, the static pressure setpoint could not be achieved because the system wasn't designed to provide maximum airflow at any one time. System diversity must be considered in order to achieve design static pressure setpoint.</p> <p>Coordination with the controls contractor and other trades was also a significant hurdle.</p>
<p>Describe any issues with the systems being tested that were not addressed by the acceptance test documents.</p>	<p>MECH-5A requires heating to be disabled while in economizer mode. This did not occur in systems with hot water heating. Therefore this question in NA. Heating can operate simultaneously since it's not controlled by the air handler. The test is intended for a packaged AHU with integrated heating, not a boiler loop.</p> <p>MECH-2A doesn't consider variation in outside airflow resulting from a fixed outside air damper position in a VAV system. This will cause the test to fail every time (false negative).</p> <p>MECH-7A describes putting the VAV system into design airflow and verifying the static pressure setpoint is met. It is difficult to attain design airflow, and proved to be much easier to put the system into full cooling to achieve the desired results. But doing so resulted in the static pressure setpoint not being met. This will always be the case in a VAV system due to system diversity, which is the design consideration that the whole building will never be in a full cooling condition.</p>
<p>How did they affect the completion of the tests?</p>	<p>The result would be either the test would pass when it should have failed (false positive) or it would fail when it should have passed (false negative).</p>
<p>Which of the following documents would you most likely use to complete the tests? Certificate of Acceptance Forms (Nonresidential Compliance Manual, Chapter 10.9 and Appendix A) At-a-glance (Nonresidential Compliance Manual, chapters 10.7-10.8). Sample test procedure (Nonresidential Compliance Manual, Chapters 10.7-10.8).</p>	<p>The technician most familiar with the tests indicated he would use all of Chapter 10 in the compliance manual.</p> <p>Most of the contractors were not familiar with these documents. They didn't have them during the test.</p> <p>Two of seven had the documents on hand.</p>

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Question	Contractor Response Summary
What sections (if any) of these documents did you find confusing?	One contractor indicated that the forms are a big improvement over the 2005 forms. They are clearer now. Some discrepancies were noted between the tests and the At-A-Glance forms.
What are some barriers to effectively completing the acceptance tests and forms?	<p>Not having access to the proper building documentation including design documents, or As-Builts.</p> <p>Not having reference documents on hand such as the compliance manual and standards manual.</p> <p>Not having building staff available.</p> <p>Not having the controls contractor available.</p> <p>Sections within each test that didn't apply to the specific system being tested resulted in NA being answered on the test but resulted in lost credibility in the test. It's easy to write NA in a specific section since there is some subjectivity to some of the questions.</p>
Is there anything extra on the acceptance testing forms that is not needed to assure the test is completed correctly?	<p>MECH-3A has a redundancy in the checklist where it refers to no heating, no cooling, and no heating or cooling.</p> <p>The headings of each test have redundant project information. It's not necessary to write this information on every page.</p>
Is there anything missing from the acceptance testing forms that is needed to assure the test is completed correctly?	<p>Full reference to the standards manual rather than just a section number is needed. It's confusing to only reference a section out of the standards manual or compliance manual. Most of the technicians interviewed were not familiar with these documents.</p> <p>MECH-7A needs a location to record the drive speed. In general there should be a location to record specific system parameters on all forms for future reference. It provides a good baseline of system performance. These documents could be useful if they could be referenced later for this performance baseline information.</p> <p>Calibration date of equipment should also be added to all forms.</p> <p>It was recommended that MECH-2A be more specific about the method used to calibrate the outside airflow. There is large variation between contractors on how they measure airflow and there needs to be better accountability of the method used.</p>
How could the procedures be improved?	<p>Improve the Intent Section of each test to make it stand out more.</p> <p>References to other documents are vague and confusing. One of the techs commented that the reference to the At-A-Glance forms was confusing and he didn't know what it was.</p> <p>Be more specific on questions to document system performance. For example, MECH-5A should require documenting actual damper position rather than just referring to 'minimum position'. On MECH-2A document damper position and static pressure.</p> <p>Organize test procedures in a more effective manner. The tests jump around a lot and are confusing. For example MECH-3A part A. Re-organize sequence of activities to prevent having to go from occupied to unoccupied repeatedly. Errors and misprints on the forms also make them confusing.</p>
If you (contractor) had previously attended training by utilities or SMACNA, did the training prepare you adequately for performing the test?	<p>Training was indicated to have been provided by SMACNA and NEBB.</p> <p>One contractor indicated he had received general Title 24 training but it didn't cover acceptance testing specifically.</p> <p>Five of nine contractors indicated they haven't received any training and of those that did receive training only one said it was relevant to acceptance tests.</p>

Title 24 Acceptance Testing Requirements and Effectiveness

Question	Contractor Response Summary
Would you prefer in-person training or print/online materials?	Of those who answered this question, three preferred in person training and two preferred on line training. It was suggested that on line training is better suited to technicians with some experience performing the tests. In person training was indicated as being more effective.
What improvements would you suggest for training?	<p>Training should include hands on training and should be specific to acceptance testing.</p> <p>Classes should be geared specifically for technicians and should focus on HVAC units.</p> <p>One of the contractors recommended there be a certification process for performing acceptance tests.</p> <p>Access to a technical resource to bounce questions off would be helpful.</p> <p>Access to literature that provides support for performing testing would be desirable.</p>
Do you have any further comments about the tests?	<p>Add references to supporting material to the tests.</p> <p>The tests should provide reference to the CEC website.</p> <p>The testing was thought of as a good thing as it keeps contractors honest, saves energy, and ensures customers get what they pay for.</p> <p>One technician commented that after performing the tests he could perform future tests much easier and quicker.</p>

Appendix E: Revised Acceptance Test Forms

This appendix summarizes the revisions to each test form. The revised test forms have been provided to the CEC for consideration.

MECH-2A

- Changed the Responsible Person's Declaration Statement to only include Contractor
- Clarified the intent statement and increased the font size
- Indicated the test can be performed in conjunction with MECH-7A due to overlapping activities
- Added reference to supporting documentation including At-A-Glance form
- Added space to document the method and the equipment used to measure airflow
- Specified sensor calibration should occur in the field either by person performing acceptance test or other
- Clarified if the system is designed to dynamically control outside air
- Added a notes section
- Included VFD speed at full cooling
- Included VFD speed at minimum flow (full heating)
- Added comment that intent of test is to ensure minimum outside airflow is achieved. VAV systems with fixed OSA dampers will provide greater OSA air than necessary at full system flow. This scenario should be mentioned in the notes section as this is an energy savings opportunity for the building.

MECH-3A

- Changed Responsible Person's Declaration Statement to include Contractor only
- Clarified the intent statement and increased the font size
- Added reference to supporting documentation including At-A-Glance form
- Added space to document the method and the equipment used to measure airflow
- Added space to document heating/cooling setpoint and deadband
- Documented pre-occupancy purge method used
- Added notes section
- Modified sequence of functional testing steps 1-8 and edited table for clarity
- Eliminated redundancy in table

MECH-5A

- Changed Responsible Person's Declaration Statement to only include Contractor
- Clarified the intent statement and increased the font size
- Added reference to supporting documentation including At-A-Glance form
- Added reference to 1.2 k Ohm resistor under possible equipment needed
- Clarified reference to standards manual
- Required that outside air sensor be field calibrated

MECH-7A

- Changed Responsible Person's Declaration Statement to include Contractor only
- Added note that MECH-7A can be performed in conjunction with MECH-2A since activities overlap
- Added reference to supporting documentation including At-A-Glance form
- Additional instrumentation to perform test to include pitot tube and drill
- Provided clarification to static pressure sensor location, setpoint, and reset control
- Added static pressure design and setpoint value to be recorded and compliance verified

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- Added static pressure reset sequence clarification
- Required field calibration of duct static pressure sensor
- Added clarification about driving all VAV boxes to full open and included VFD speed
- Added comment about diversity in system resulting in static pressure setpoint not being met with all VAV boxes full open. Added notes section
- Added clarification to Step 2 regarding driving all VAV boxes to minimum flow (full heating) and added space for VFD speed at this condition

MECH-9A

- Changed Responsible Person's Declaration Statement to include Contractor only
- Added reference to supporting documentation including At-A-Glance form
- Clarified the intent statement and increased the font size
- Added instrumentation to perform test and calibration date
- Required supply water temperature sensor to be field calibrated
- Added notes section
- Revised Step 1 format for clarification
- Revised Step 3 title

MECH-10A

- Changed Responsible Person's Declaration Statement to include Contractor only
- Added reference to supporting documentation including At-A-Glance form
- Clarified the intent statement and increased the font size
- Added instrumentation to perform test and calibration date
- Provided clarification to static pressure sensor location, setpoint, and reset control requirements
- Required supply water pressure sensor to be field calibrated
- Added notes section
- Revised Step 1 Minimum/Low Flow Test
- Added note for conversion from ft. w.c. to psig
- Revised Step 2 Maximum/Design Flow Test

LTG-2A

- Changed Responsible Person's Declaration Statement to include Contractor only
- Improved visibility of Intent section
- Added reference to supporting documentation including:
 - As built and/or design documents
 - 2013 Building Energy Efficiency Standards Nonresidential Compliance Manual At-A-Glance
 - 2013 Building Energy Efficiency Standards Manual
- Included section to record automatic time switch settings Provide reference to Certified Appliance and Control Devices database
- Formatted test to clearly identify separate test procedures
- Clarified the Manual Daylighting Control functional test: Identify lighting control device types as OS, MDC, and ATSC Identify 2013 Building Energy Efficiency Standards Manual where referenced
- Added notes section after each functional test
- Provided clarification for exempt lighting definition

LTG-3A

This test was edited in its entirety to be more understandable and easier to conduct the test

- Changed Responsible Person's Declaration Statement to include Contractor only
- Clarified the section that identifies which test(s) are included in the submittal

Title 24 Acceptance Testing Requirements and Effectiveness

- Edited Construction Inspection:
- Add reference to supporting documentation including including:
- As built and/or design documents
- 2013 Building Energy Efficiency Standards Nonresidential Compliance Manual At-A-Glance
- 2013 Building Energy Efficiency Standards Manual
- Removed reference to type of control system
- Changed Y/N responses to check boxes
- Added definition of open loop and closed loop sensors
- Added content for clarification
- Added reference to 2013 Building Energy Efficiency Standards Manual
- Added reference to CEC website
- Reorganized test sequence by dimming controls type rather than measurement method used
- Reformatted each test to be more consistent with other acceptance test forms
- Provided definition of Illuminance and Distance Methods
- Changed the test sequence and instructions to be more consistent with At-A-Glance document
- Changed content of test procedures to allow testing to be completed as outlined in the At-A-Glance document
- Simplified the test to make it more understandable and easier to follow